EUVL into production with ASML's NXE platform

Content

- Introduction
- ASML EUV product roadmap
- Outlook to 2020
- Summary & conclusions

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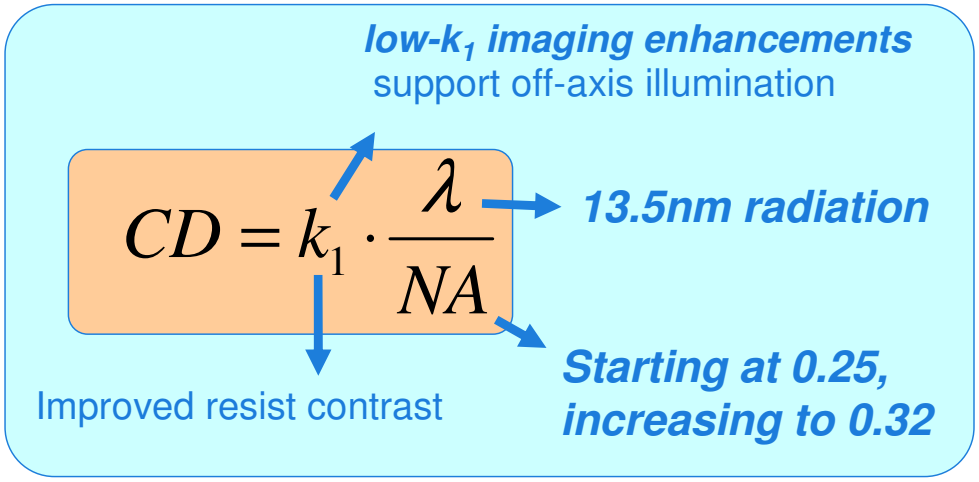
EUV lithography is optical lithography

- Resolution scales with numerical aperture and illumination wavelength (13.5nm → 14x leverage to 193nm).
- Throughput scales with source power and system transmission.
- Rigid mask can be patterned and repaired using the same processes as for ArFi masks (additions to infrastructure, not a new mask infrastructure).



conventional illumination possible
off-axis illumination required
NA too small, even with off-axis illumination

HP \ NA	0.25	0.32	0.35	0.40	0.45
27 nm	0.50	0.64	0.70	0.80	0.90
24 nm	0.44	0.57	0.62	0.71	0.80
22 nm	0.41	0.52	0.57	0.65	0.73
18 nm	0.33	0.43	0.47	0.53	0.60
16 nm	0.30	0.38	0.41	0.47	0.53

k_1 as function of NA and resolution

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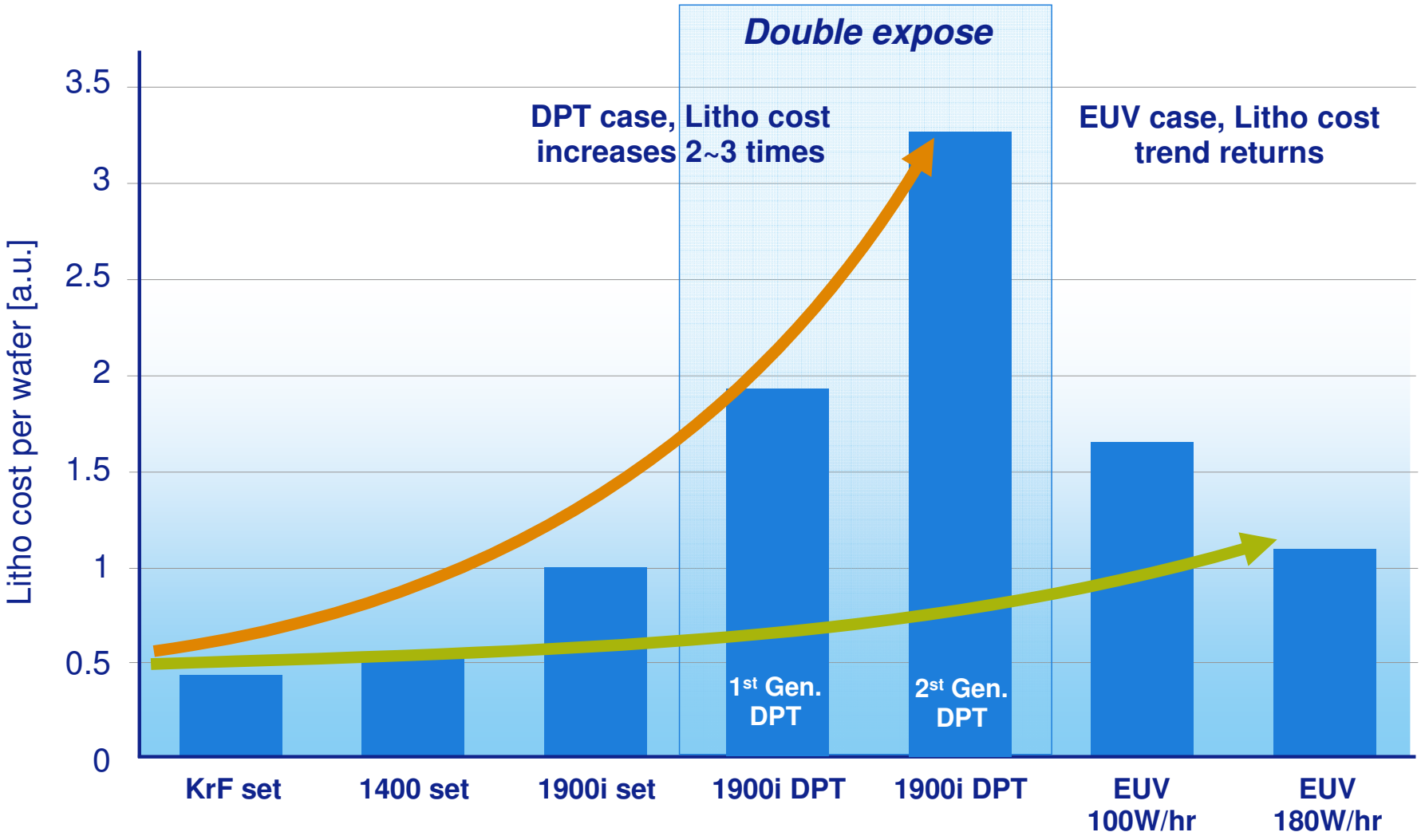
Litho costs come back to normal with 100wph EUVL



Source: Samsung, EUV Symposium, Prague, Oct 2009

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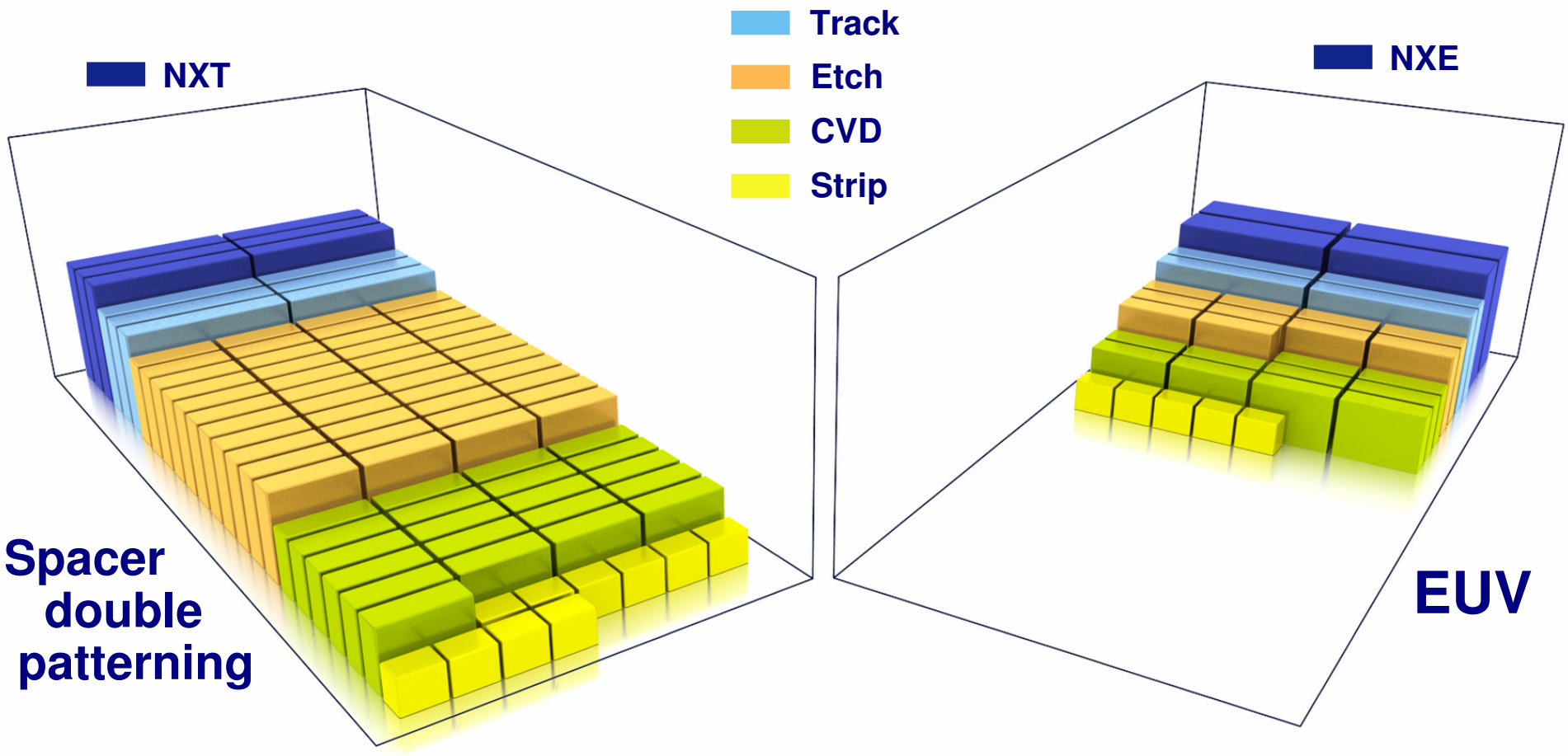
EUVL can increase the fab capacity ~2x

Larger footprint required to support Multi Patterning schemes



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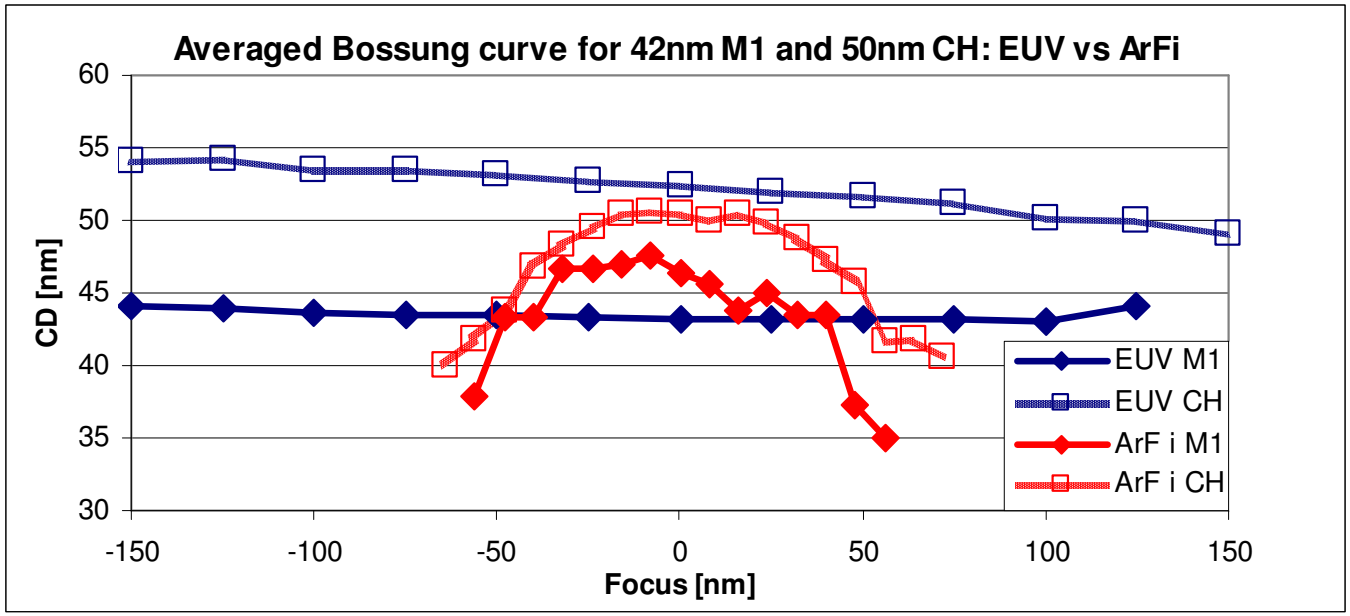
Single – expose EUVL: the way to go!

Process window analysis illustrates the benefit of high-k_1 imaging



Process window analysis	EUV	ArF i
Depth of Focus – Metal-1 [nm]	>300	~100
Depth of Focus – Contact Hole [nm]	>300	~130

22nm node SRAM:
- 42nm HP Metal-1
- 50nm HP contact hole

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ASML EUV product roadmap

Source roadmap in place for cost effective production

	2006 Proto System	2010 NXE:3100	2012 NXE:3300B	2013 NXE:3300C
Qualification CD	32 nm	27 nm	18 nm	16* nm
NA / σ	0.25 / 0.5	0.25 / 0.8	0.32 / 0.2-0.9	0.32 / OAI
Overlay (SMO)	< 7 nm	< 4.5 nm	< 3.5 nm	< 3 nm
Throughput	4 W/hr	60 W/hr	125 W/hr	150 W/hr
Dose, Source	5 mJ/cm^2, ~8 W	10 mJ/cm^2, >100 W	15 mJ/cm^2, >250 W	15 mJ/cm^2, >350 W

Main improvements
1) New EUV platform: NXE
2) Improved low flare optics
3) New high sigma illuminator
4) New high power source
5) Dual stages

Main improvements
1) New high NA 6 mirror lens
2) New high efficiency illuminator
3) Off-axis illumination optional
4) Source power increase
5) Reduced footprint

Platform enhancements
1) Off-Axis illumination
2) Source power increase

* Requires <7 nm resist diffusion length

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EUV process viability confirmed by two 0.25 NA Systems

imec

COLLEGE OF NANOSCALE SCIENCE & ENGINEERING
UNIVERSITY AT ALBANY State University of New York

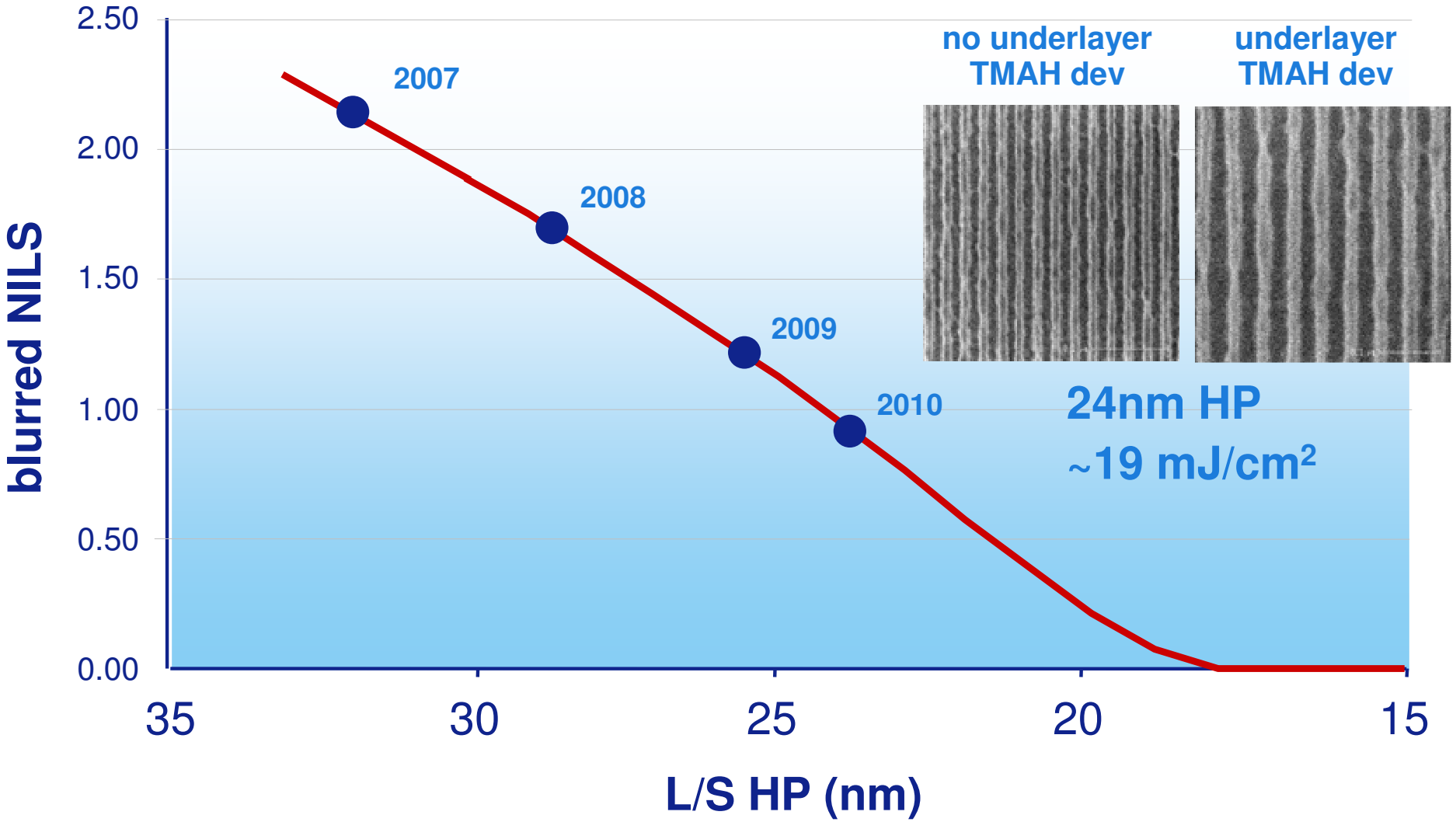
λ	13.5 nm
NA	0.25
Field size	26 x 33 mm^2
Magnification	4x reduction
Sigma	0.5

- 300mm Single stage
- linked to track
- Single reticle load
- Uses TWINSCAN technology
- Sn discharge source

SONY intel Micron
hynix GLOBALFOUNDRIES
Panasonic SAMSUNG
SEMATECH ELPIDA
TOSHIBA
tsmc PSC
IBM infineon ASML

24nm champion resolution on 0.25NA/0.5σ system

From ~32nm half-pitch in 2007 to 24nm in 2010



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  - NXE:3300B
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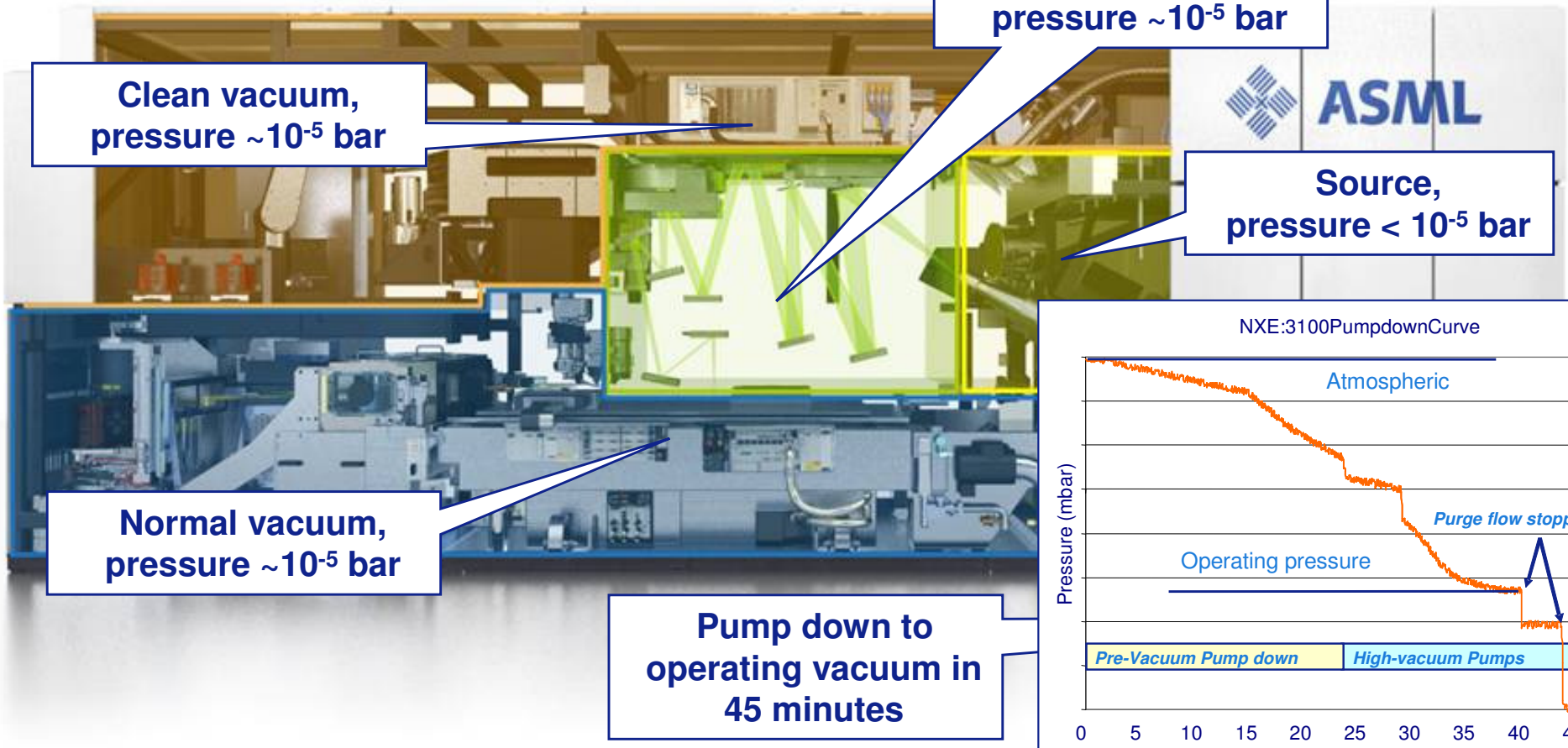
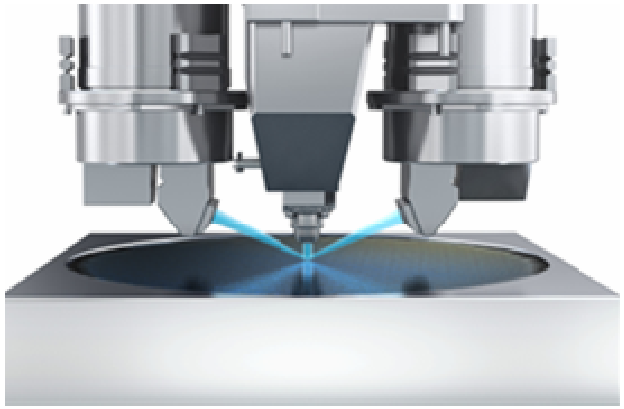
NXE:3100 pumps to operating pressure in ~45 min.

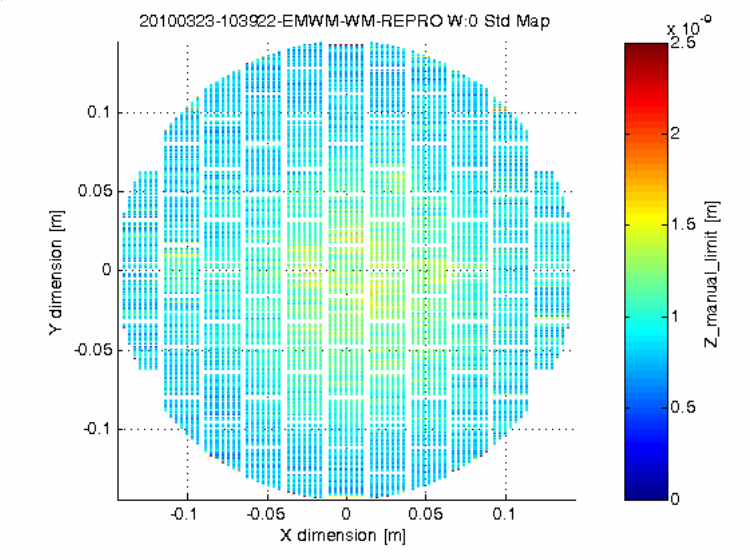
- Vacuum levels are similar throughout the tool, and there are different cleanliness requirements to prevent contamination of the optics.



NXE wafer metrology is verified in vacuum

Focus and Levelling

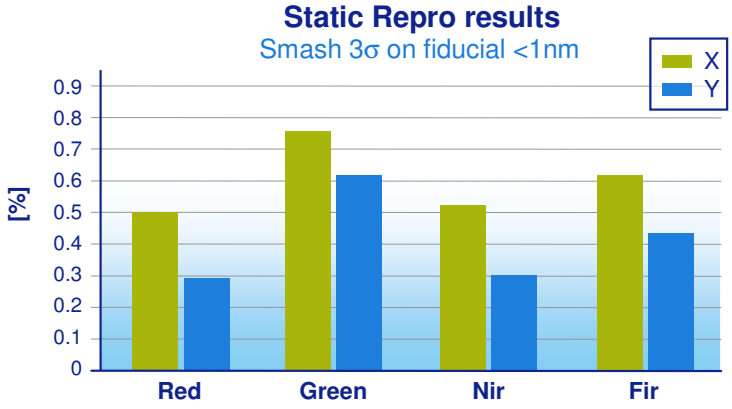


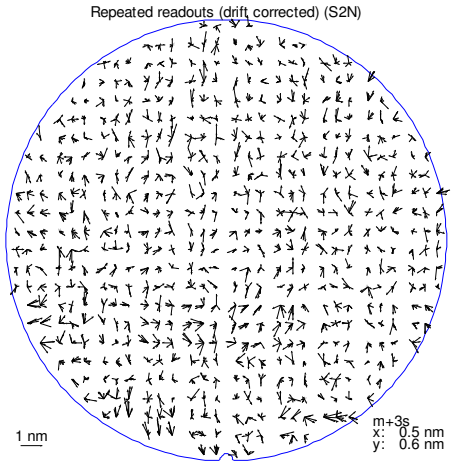


Mean standard deviation over wafer: 0.9 nm

99.7% value of standard deviations: 1.6 nm

Alignment





Multiple wafer readout 3σ = 0.6 nm

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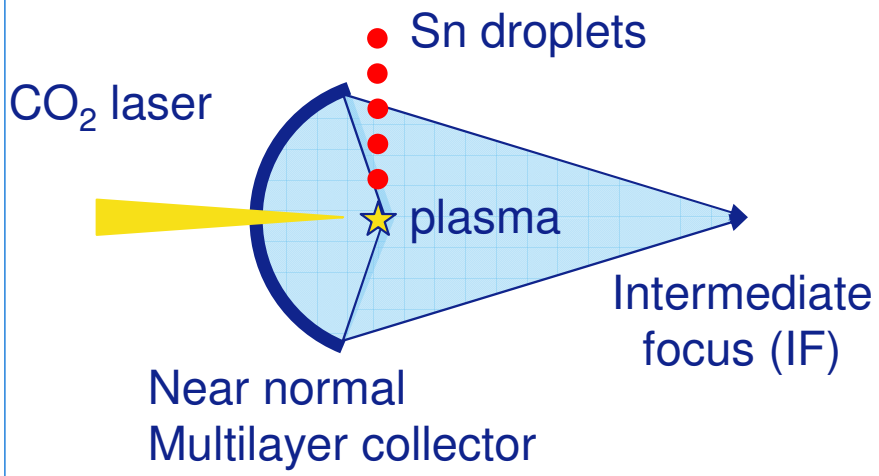
The 13.5nm light source: two concepts

Laser-Produced Plasma (LPP)

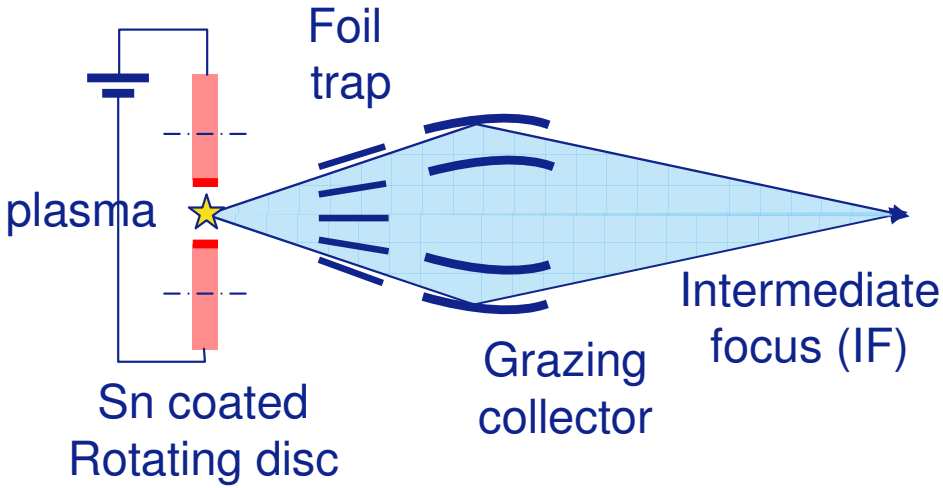
- CO_2 laser creates tin plasma which emits EUV radiation
- Debris mitigation by trap and background gas



Cymer, Komatsu-GPI

Electrical Discharge (DPP)

- High voltage creates tin plasma which emits EUV radiation
- Debris mitigation by rotating foil trap



Ushio

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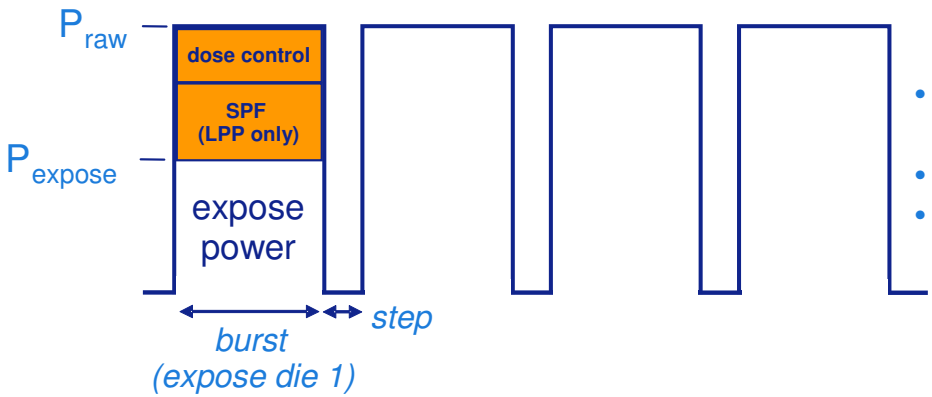
Source performance roadmap towards 105 W

- ASML has received three LPP sources and one DPP source
  - Power for both concepts will be upgraded in two steps.

		LPP		DPP	
Timing	**Source Config**	**Expose Power**	**Throughput**	**Expose Power**	**Throughput**
Q3/2010	Integration	1W	<1wph*	3W	2wph**
Q4/2010	Integration	7W	4wph	15W	10wph
Q1/2011	Upgrade 1	40W	25wph	65W	35wph
Mid 2011	Upgrade 2	100W	60wph	100W	60wph

* integrated with NXE:3100
** predicted



- **D**uty **C**ycle =
  burst / (burst + step)
- dose control loss ~20%
- SPF loss ~30%

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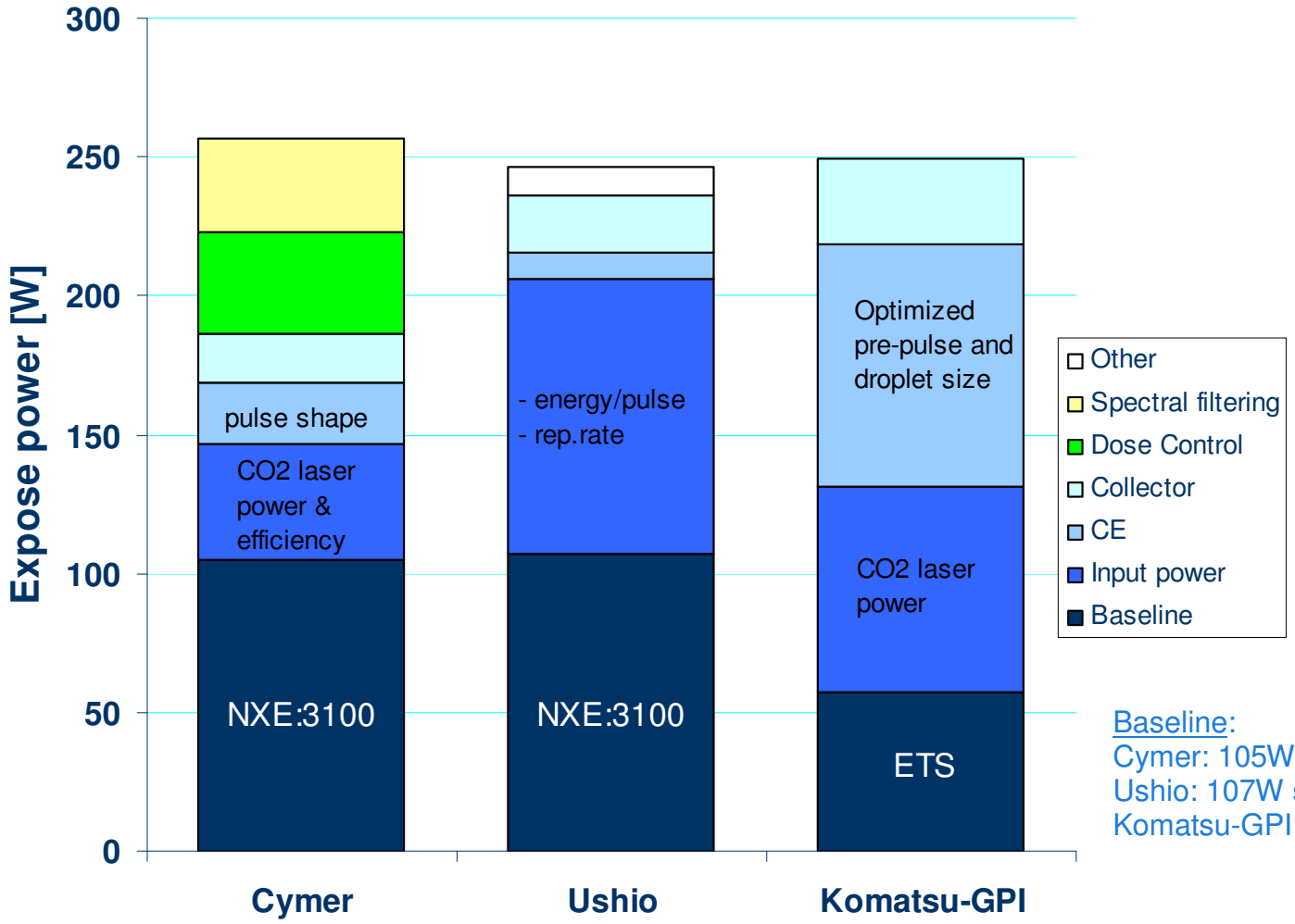
Source supplier roadmaps in place towards 250 W

Needed for 125 wph at 15 mJ/cm² on NXE:3300B



Baseline:
Cymer: 105W source for NXE:3100
Ushio: 107W source for NXE:3100
Komatsu-GPI: ~50W prototype

Source:
Komatsu-GPI, Cymer, and Ushio,
EUV Lithography Symposium, Kobe, Japan (Oct. 2010)

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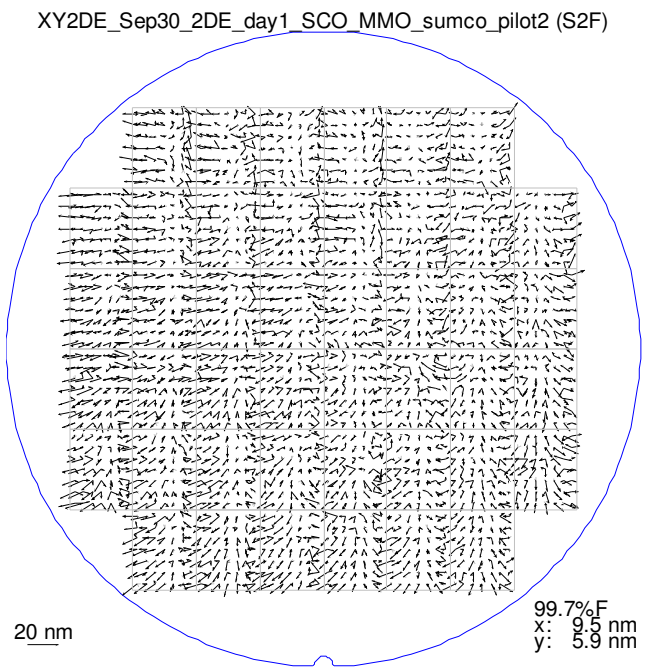
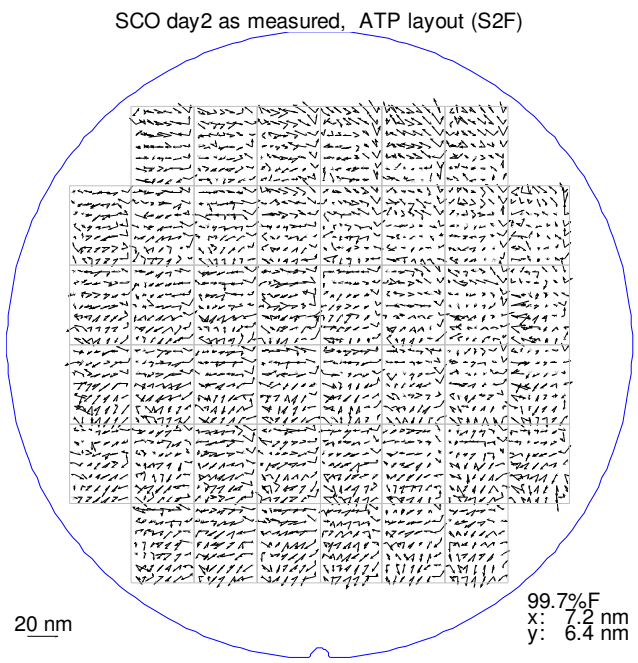
Multi-day overlay stability demonstrated

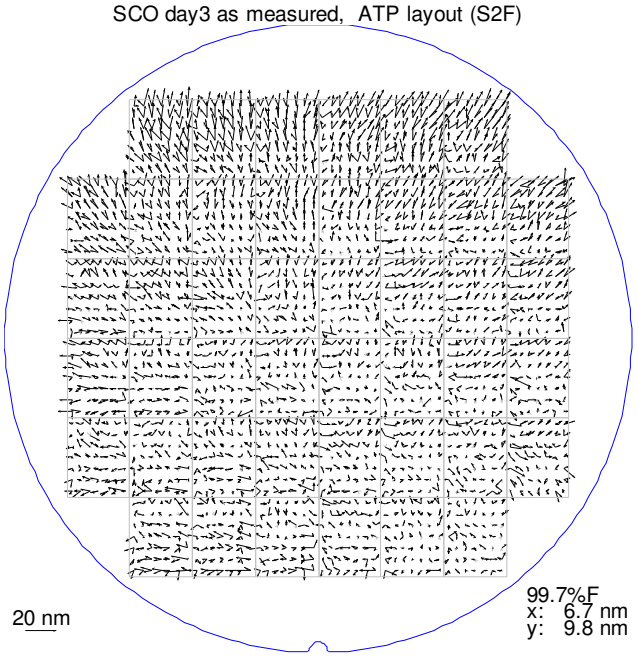
- 3 day single chuck overlay on NXE:3100
  - Stability shown, performance improvement ongoing



(9.5,5.9)



(7.2,6.4)



(6.7,9.8)

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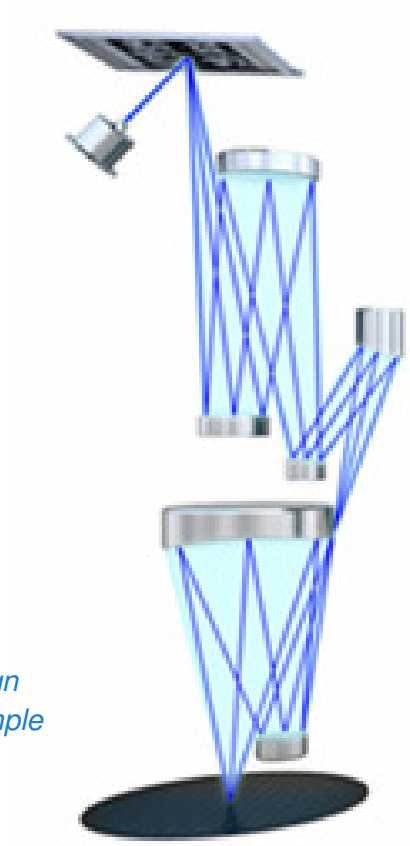
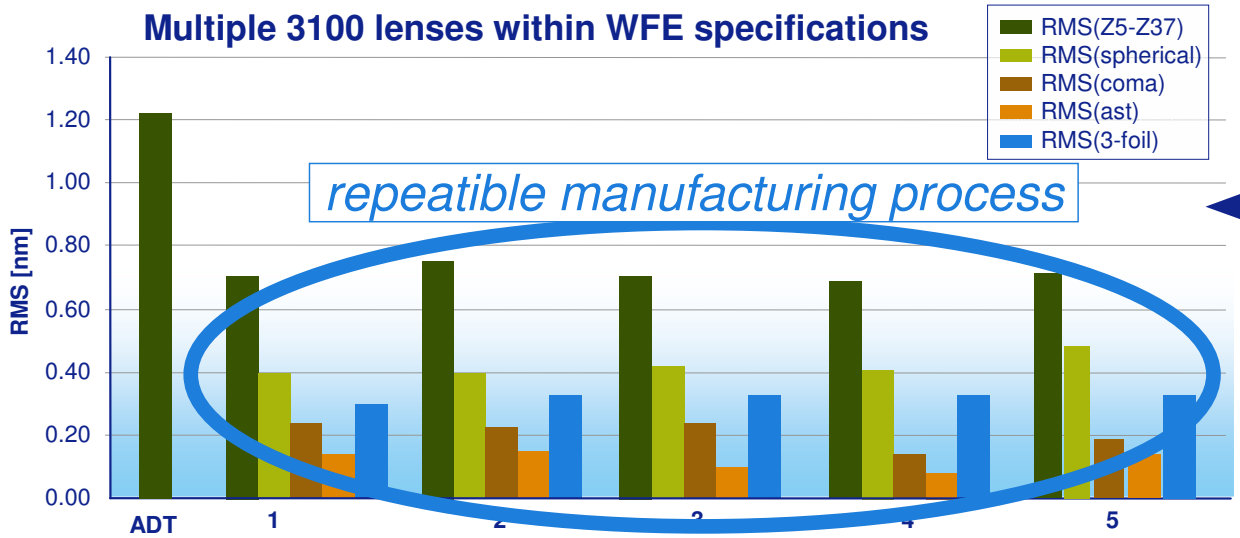
Multiple 3100 lenses manufactured and qualified

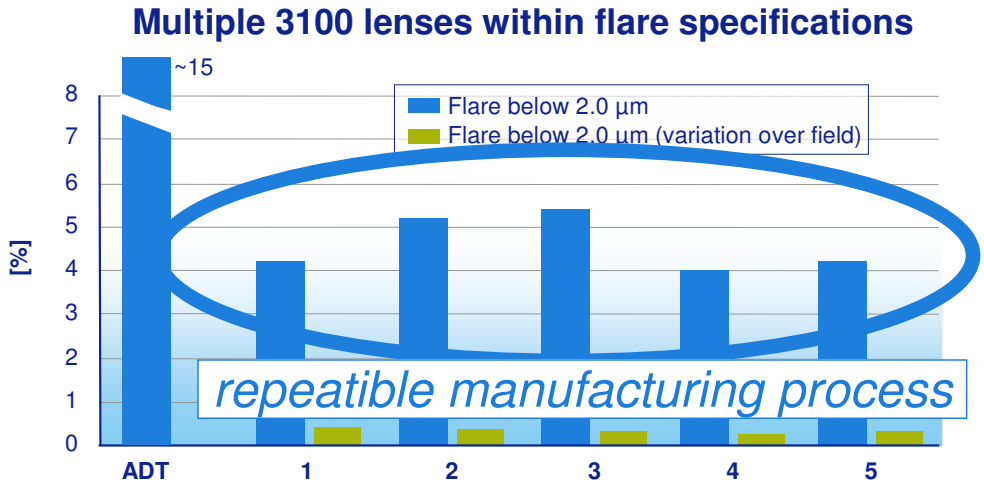
Wavefront qualified by EUVL interferometer



design example

- NA: 0.25
- Field size: 26mm
- Chief ray at mask: 6°
- 4x reduction ring field design
- Design is extendable to higher NA





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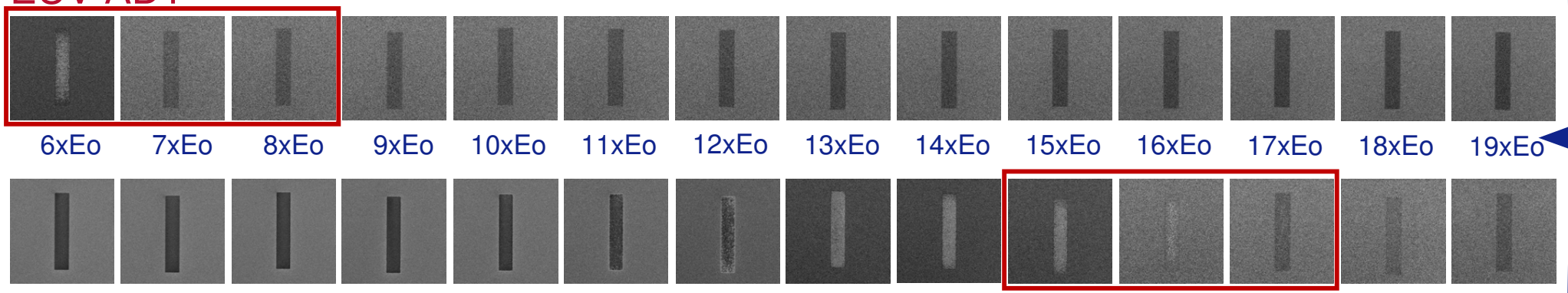
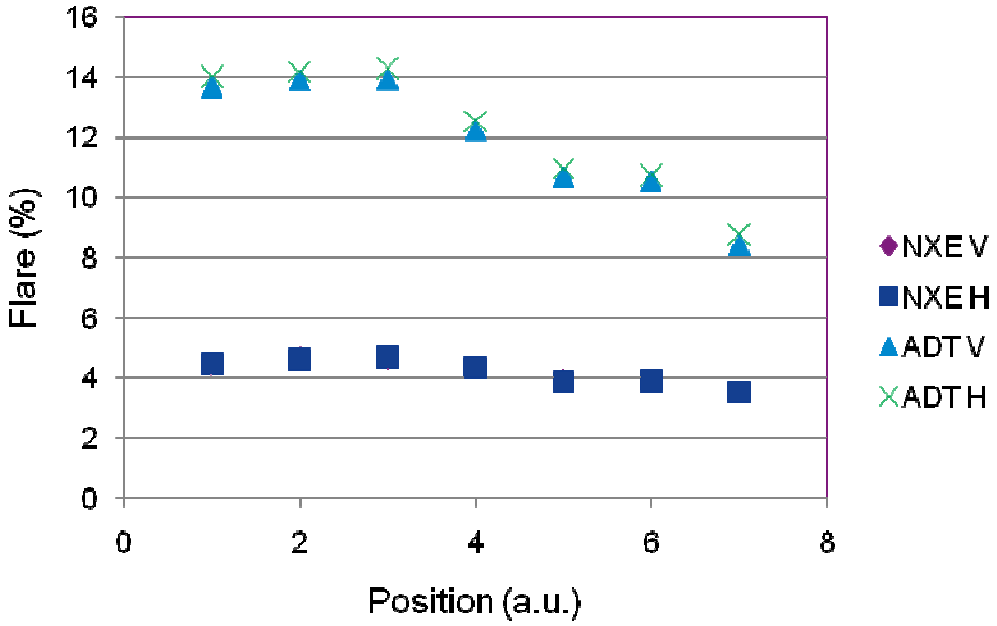
NXE:3100 flare measurement in resist confirms Zeiss calculation of <5%

EUV ADT



NXE 3100

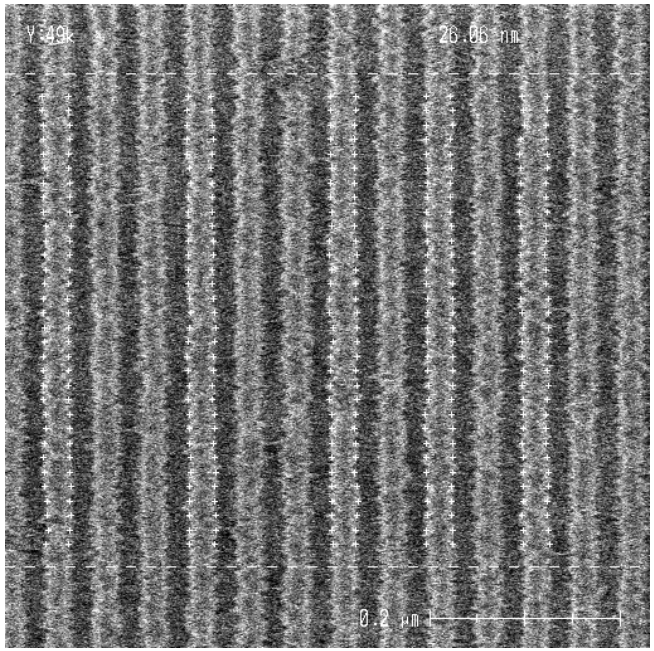


0.25NA proto: flare = 14%
0.25NA NXE:3100: flare = 4.7%

courtesy of IMEC

NXE:3100 Imaging – smaller and smaller…

25nm HP



Next step is processing optimization:
rinse, develop process and underlayer (exposures done on bare Si wafer)

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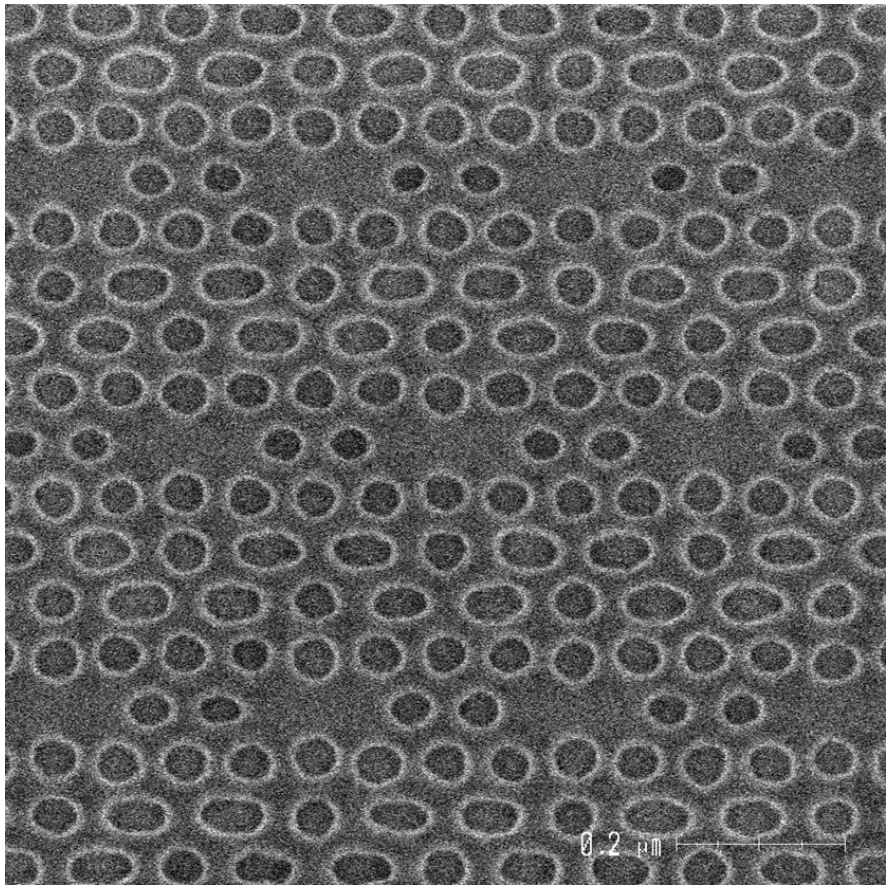
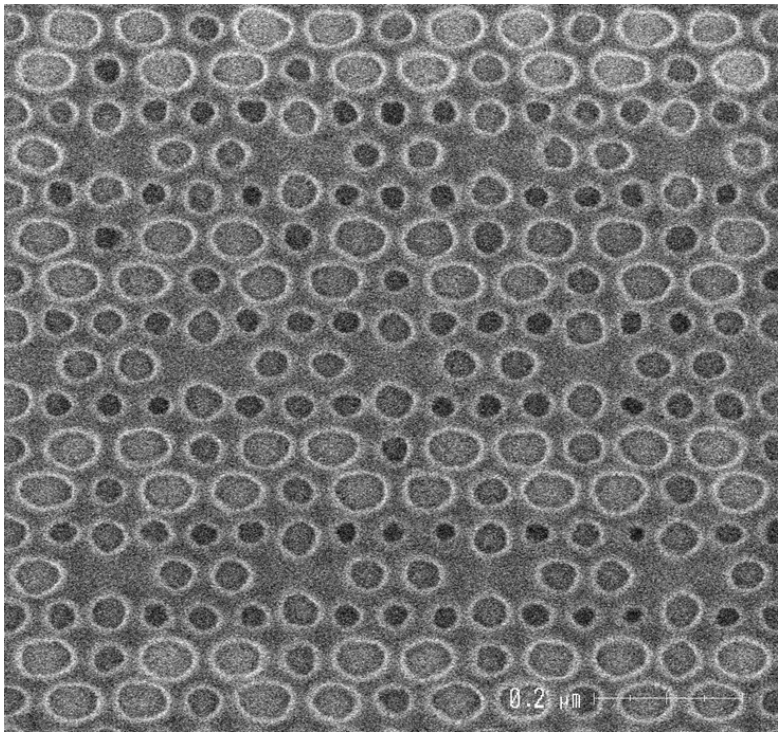
NXE:3100 16nm node SRAM contacts successfully exposed



Cell-size = 0.048 µm^2



Cell-size = 0.038 µm^2

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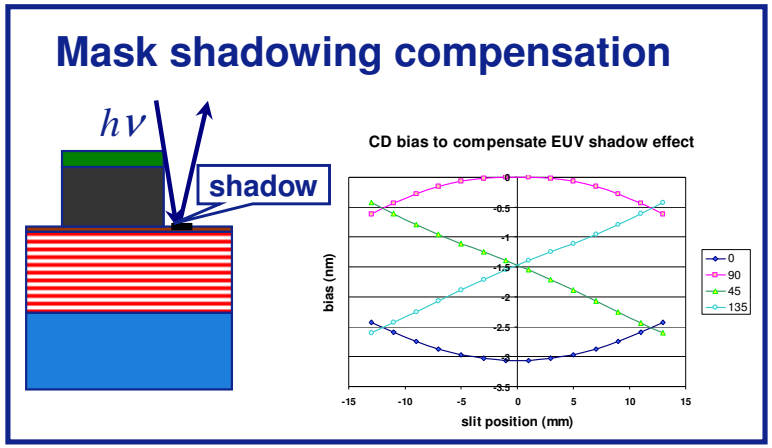
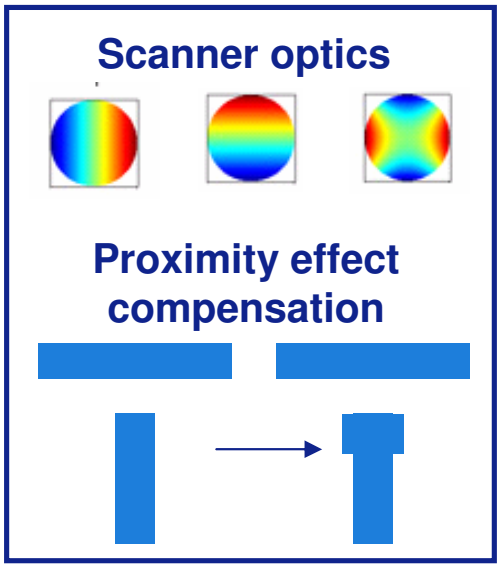
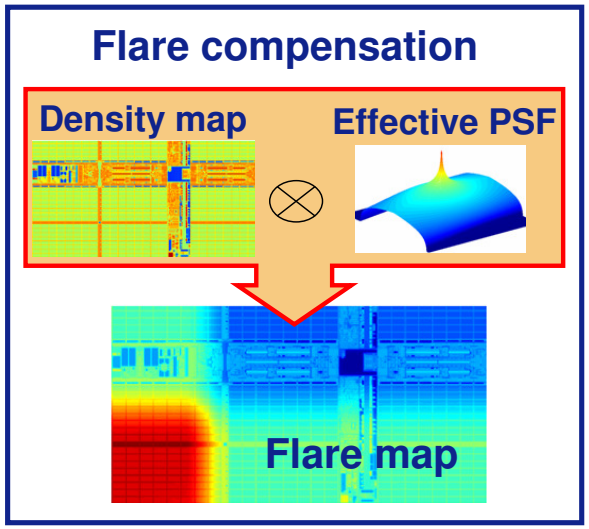
Brion's Tachyon NXE announced @ BACUS 2010

- New EUV product, seamlessly integrated with Tachyon applications.
- Enables accurate, compact, and fast full field EUV predictions
  - includes full-field flare modeling, shadowing, and proximity effects
- Incorporates NXE:3x00 scanner characteristics, models, and data that accurately describe the optical performance of the system.
- Delivers NXE:3x00 optimized CD uniformity & correct pattern placement.
- Decreases EUV mask re-spins and shortens mask development cycles.







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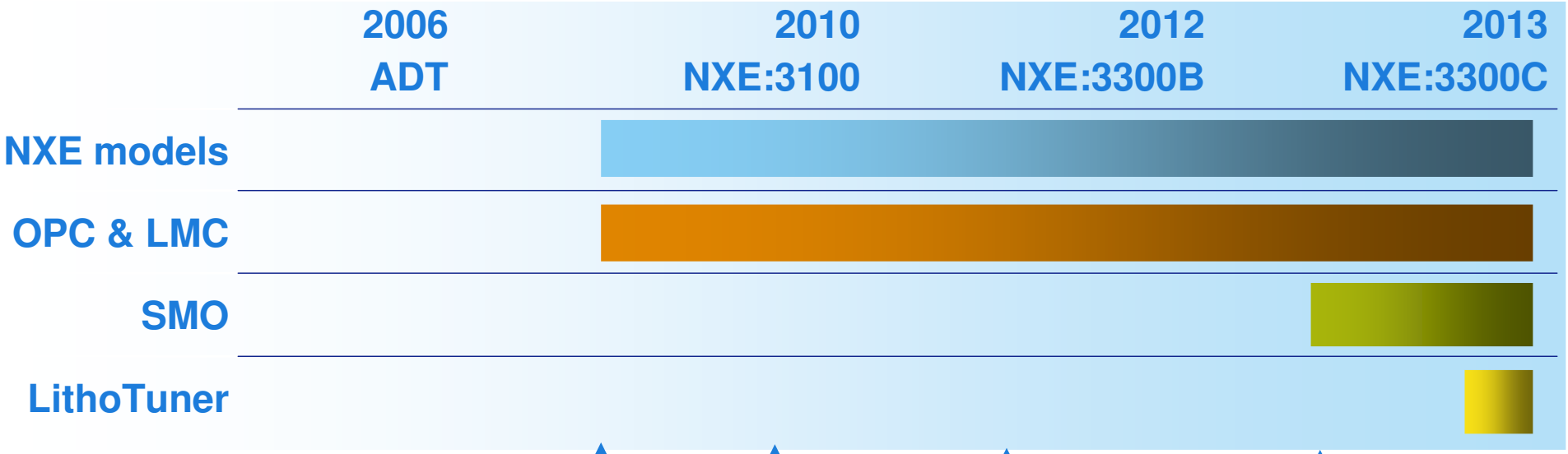
Brion EUVL computational lithography roadmap

Accurate predictive modeling for ASML EUV scanners



2009.09 release

1. Beta release
2. Modeling, correction and verification for flare, mask shadowing and low k_1 proximity effect

2010.06 release

1. Production release
2. Models: NXE:3100
3. Optimized Process Correction (OPC)
4. OPC Verification (LMC)

2011.06 release

1. Models: NXE:3100, NXE:3300B

2012.06 release

1. Models: NXE:3100, NXE:3300B, 3300C
2. NXE SMO
3. LithoTuner (TBD)

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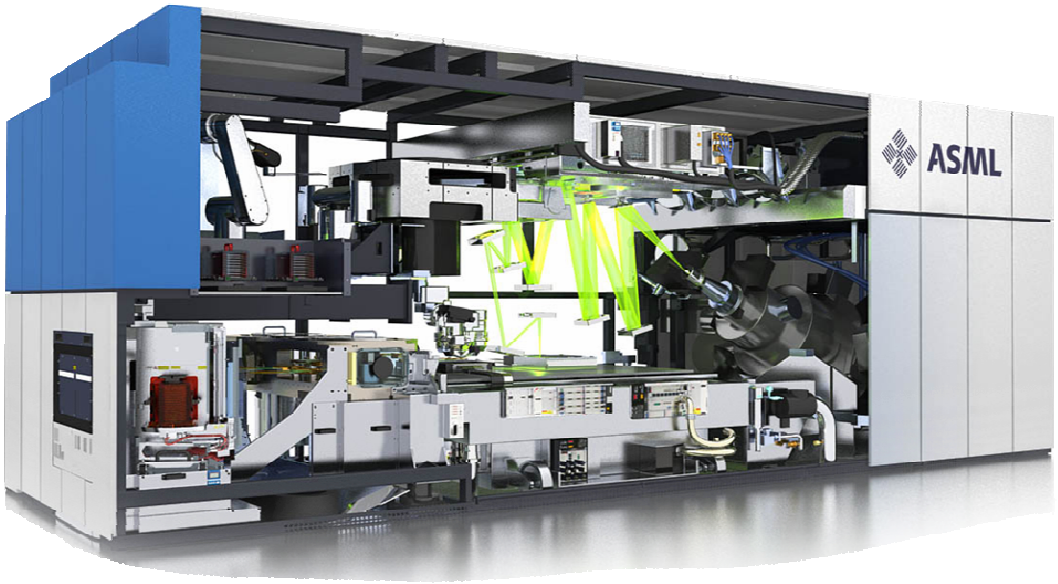
The NXE:3300B is the second product build upon the NXE-platform H1 2012

- Higher 0.32 NA optics and reduced foot-print for
  - improved resolution of 18 nm with off-axis illumination
  - Improved OV in line with device requirements
  - improved cost-of-operation:
    - higher productivity at higher dose
    - off-axis illumination without energy loss



System performance	NXE:3300B
NA	0.32
Resolution (half-pitch)	22 nm (18 nm with OAI)
Overlay (DCO / MMO)	< 3.5 / 5.0 nm
Throughput	125 wph @ 15 mJ/cm^2

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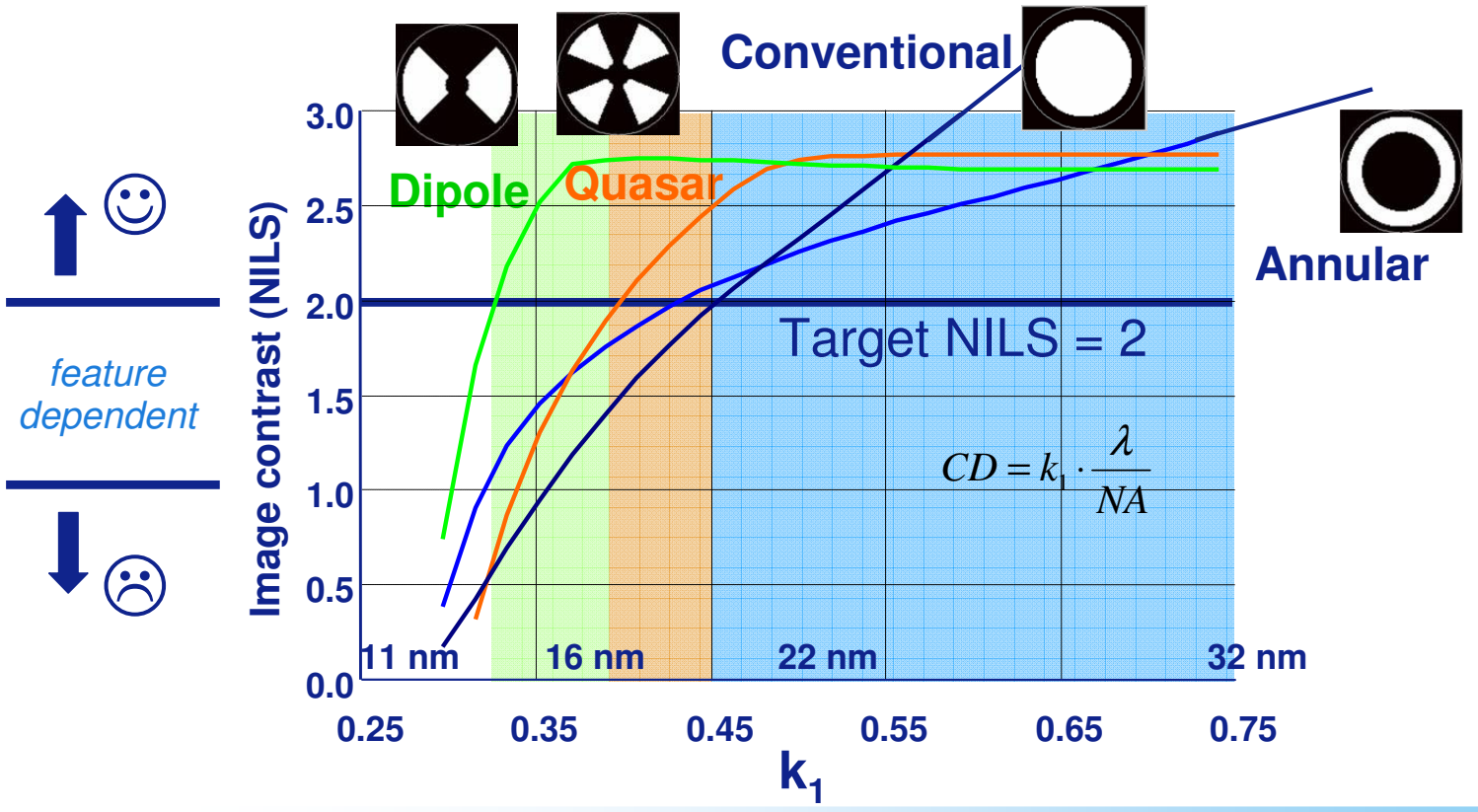
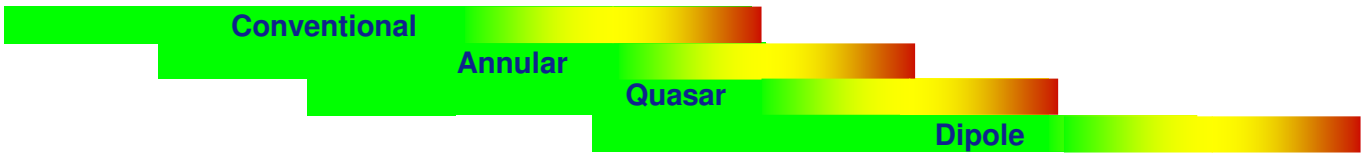
Further resolution improvement with off-axis illumination

With dipole illumination resolution improves to below 16 nm



half pitch	32 nm	28	24	22 nm	20	18	16 nm	13	11 nm
k1	0.76	0.66	0.57	0.52	0.47	0.43	0.38	0.31	0.26



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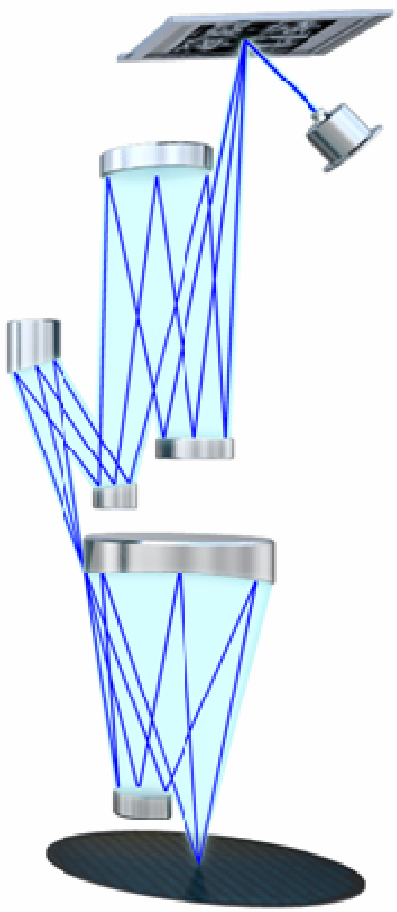
Six-mirror lens design is extendable to 0.32 NA

Resolution improves from 27 to 18 nm with off-axis Illumination

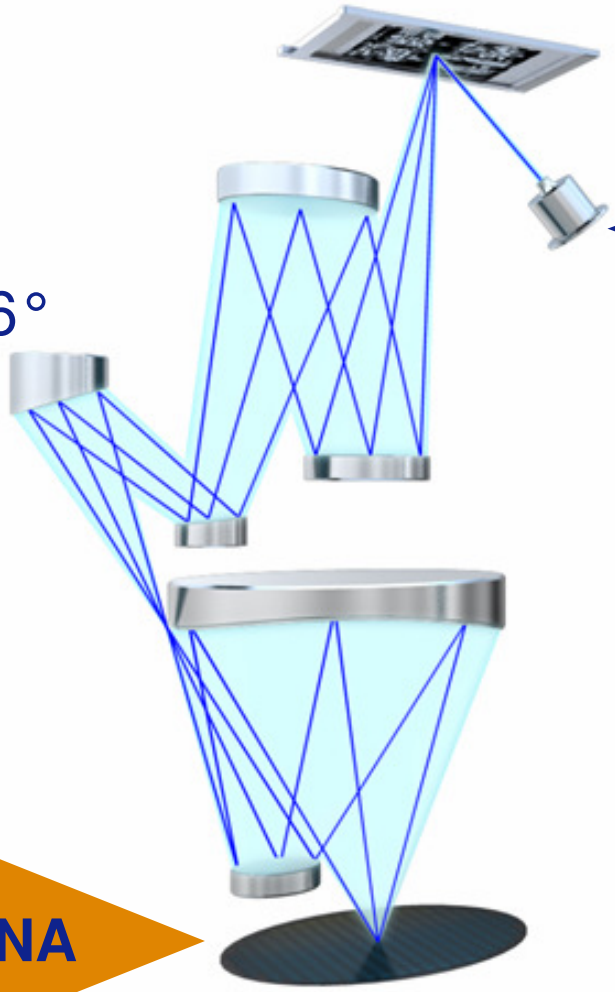


Field size remains 26 mm

Chief ray at mask remains 6°

- Main technical changes:
  - Larger mirrors
  - Steeper aspheric mirrors
  - High angles of incidence

0.25 NA → **0.32 NA**



design examples

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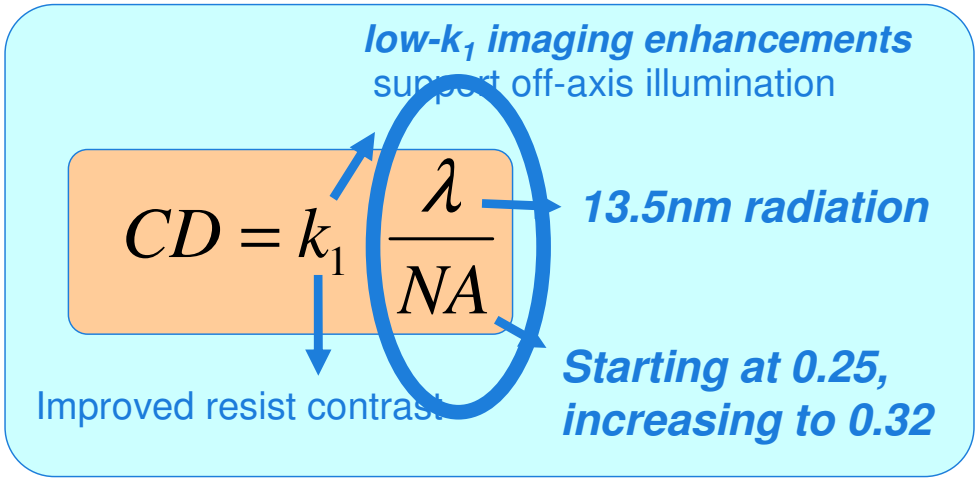

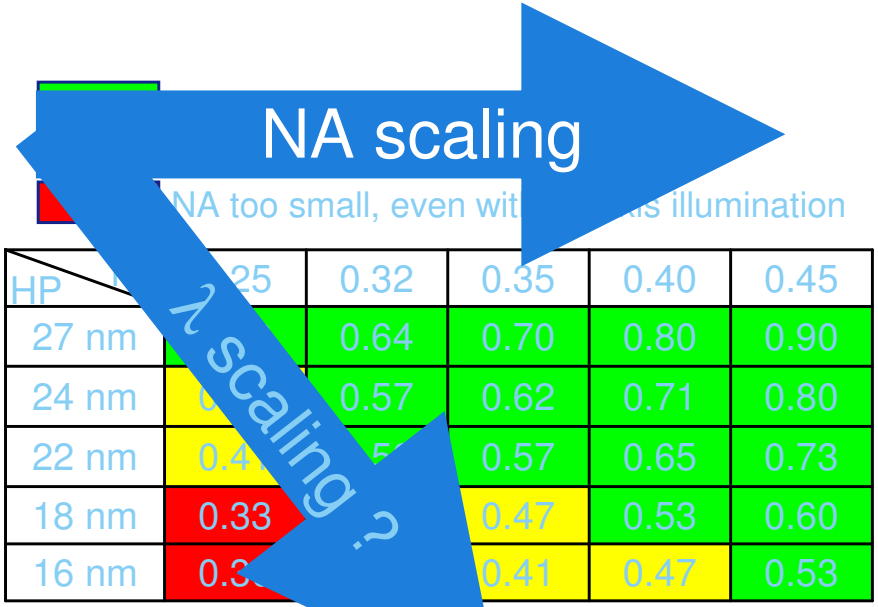

k_1 as functi A and resolution

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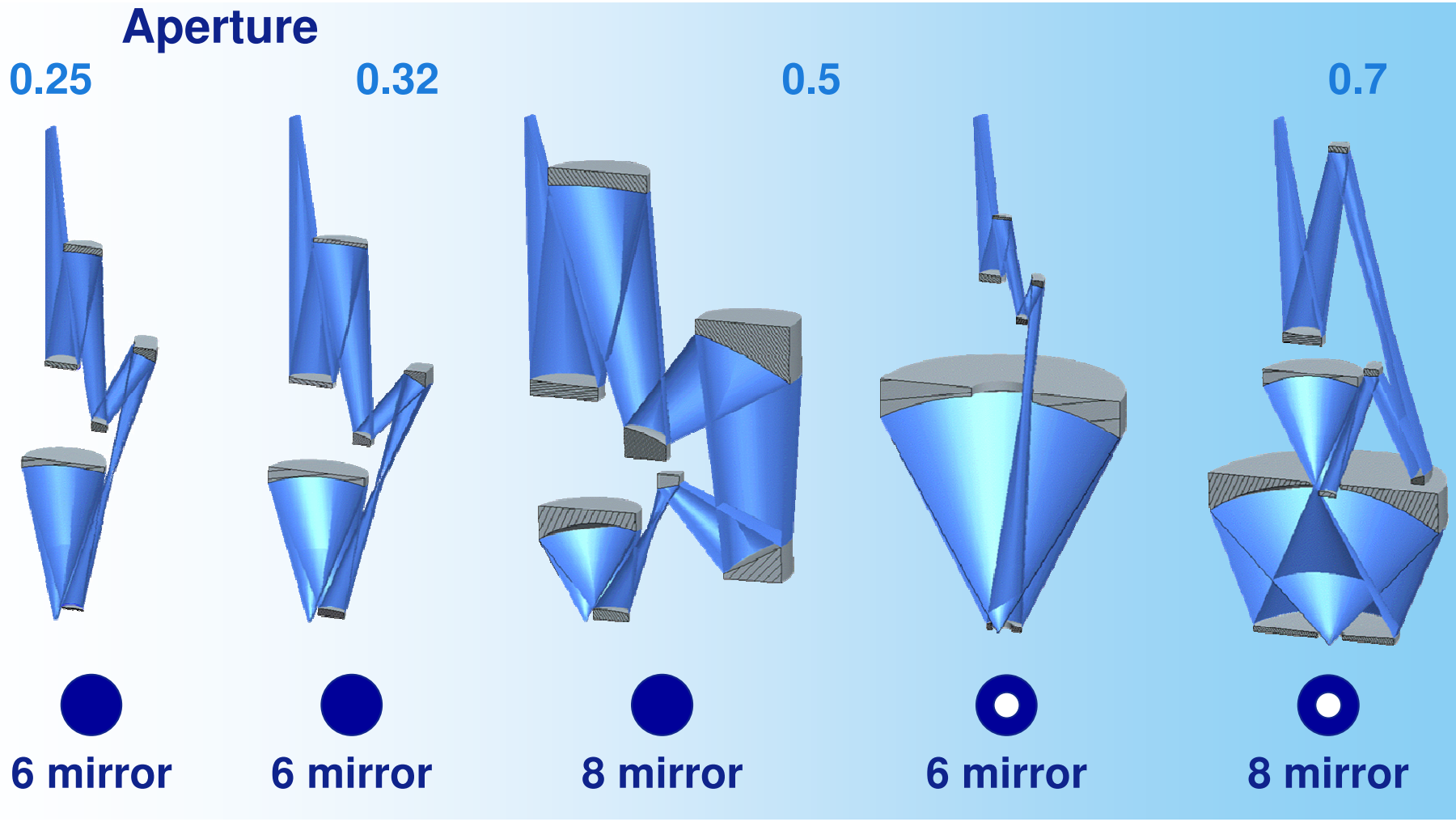
EUV extendibility possible beyond 10 nm resolution

Through increase of the aperture up to 0.7



design examples

Reference: W. Kaiser *et al.*, SPIE 2008 6924-4

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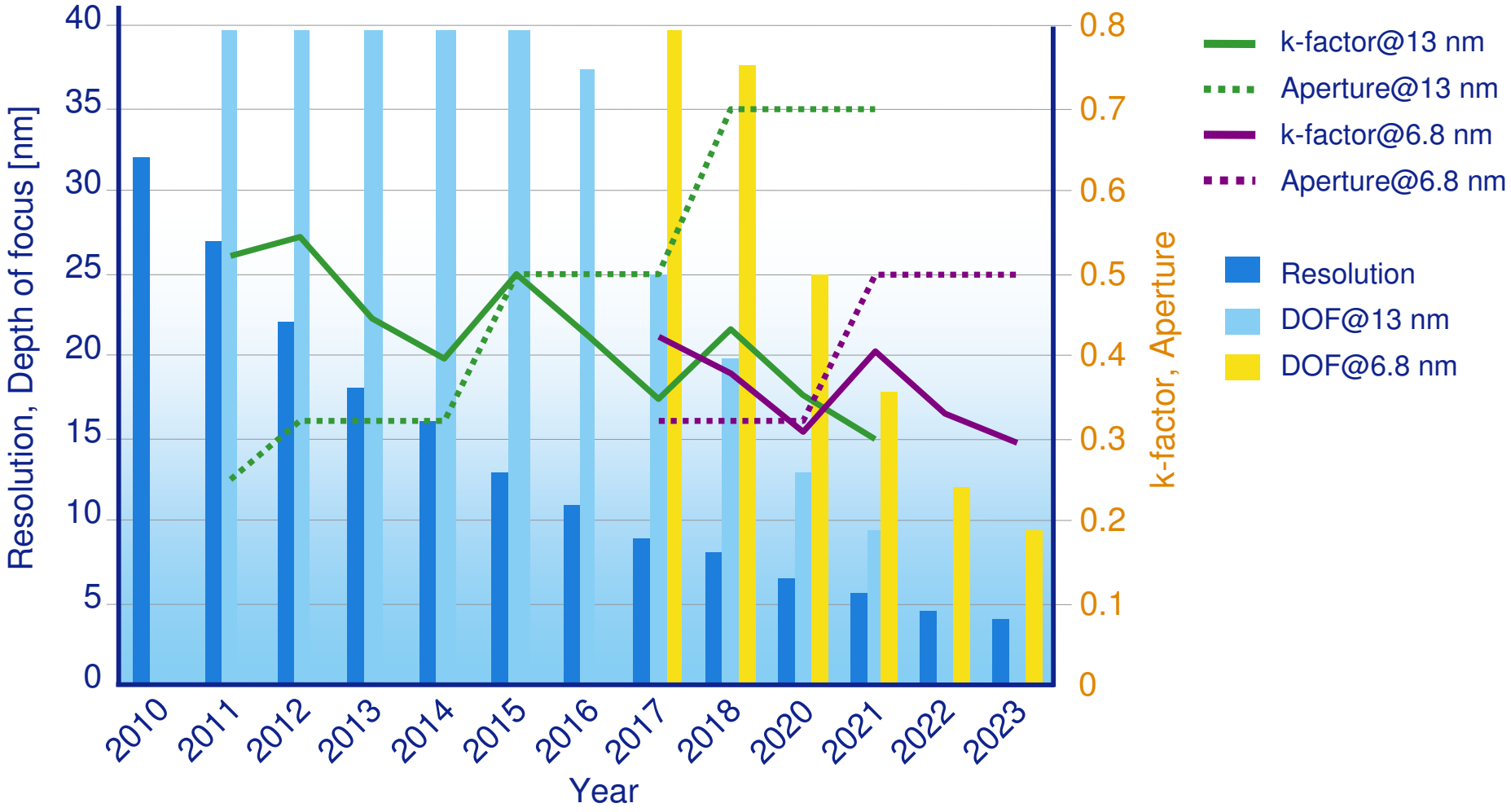
Extendibility of EUVL down to sub-5nm possible

Increasing apertures up to 0.7, wavelength reduction down to 6.8 nm, using 13 nm compatible optics with depth of focus as the major challenge



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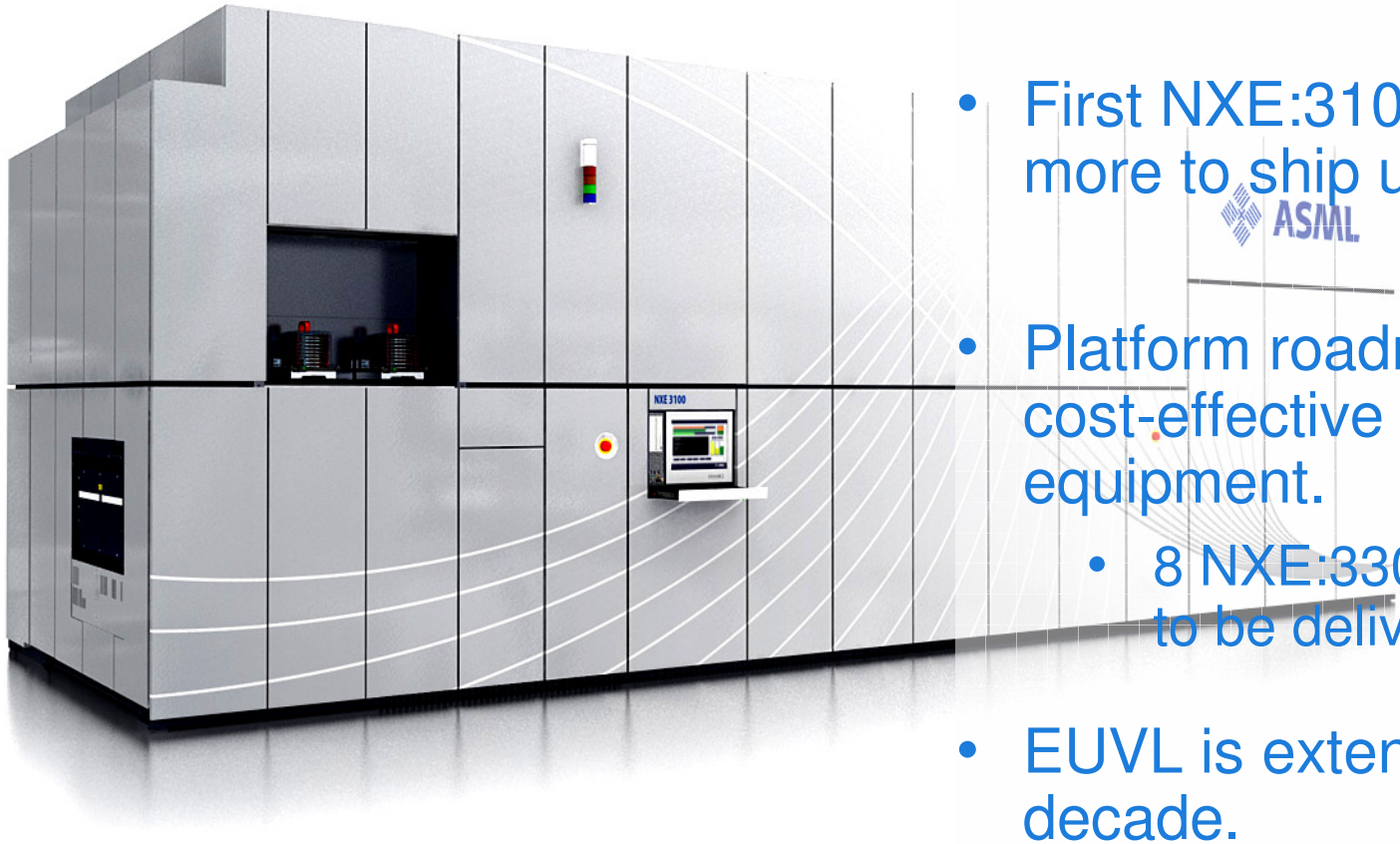

- Imaging of 27nm HP L/S shown; resolution 24 nm HP.
- First NXE:3100 system shipped, 5 more to ship until mid-2011.
- Platform roadmap in place to offer cost-effective EUV production equipment.
  - 8 NXE:3300B systems ordered; to be delivered starting 2012.
- EUVL is extendible over the next decade.

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